TORNADO AT MAPLE PLAIN, MINN.

A destructive tornado visited Maple Plain and other points in the western portion of Hennepin County, Minn., during the evening of Sunday, August 18, 1907. Some mention of the storm is made in the August report of the Minnesota section of the Climatological Service, edited by Mr. U. G. Purssell, section director, who has sent us the original accounts. We are chiefly indebted to Mr. George W. Richards, the cooperative observer of the Weather Bureau at Maple Plain, which is about twenty miles west of Minneapolis.

According to Mr. Richards the hour was 7:35 p. m. The day had been warm and oppressive, the maximum temperature during the afternoon being 88°, and heavy, threatening clouds preceded the appearance of the tornado. No funnel-shaped cloud was observed, but there may have been such a cloud, obscured from view by the heavy downpour of rain.

The path of destruction varied in width from a few rods to a quarter of a mile. The severity of the storm was first felt near Lyndale, 4 miles southwest of Maple Plain, where grain and haystacks were torn down and scattered. Thence it moved northeast to Armstrong, 1 mile west of Maple Plain, where it did great damage to a barn, a graveyard, and the fields in its path. The tornado crost the railroad track half a mile west of Maple Plain and continued thru a belt of timber and an orchard, blowing down or breaking off many telegraph poles and trees. The greatest damage was done about a mile or more northeast of Maple Plain, where the tornado swept down a hill and with seemingly increased energy traveled along the southern shore of Lake Independence, demolishing several cottages and barns, in which many persons were injured, one of them fatally.

To the east of the lake the tornado laid flat a great deal of timber, and continuing toward Osseo did much damage in the vicinity of that town, which is 15 miles east-northeast of Maple Plain. The general direction of the motion of the storm was from west-southwest to east-northeast and the path was about 20 miles in length. The storm was evidently a tornado, as on the south edge of the path the trees were blown from the southwest or south, while on the north side the trees were blown from the northwest. Outside of the path of destruction a heavy windstorm prevailed. At Maple Plain 0.12 inch of rain fell Sunday morning and 1.70 inches in the evening.

It is worth noting that at 10 a. m. on the forenoon of the 18th a very severe wind and hailstorm had occurred 2 or 3 miles southeast and south of Maple Plain, a narrow strip extending from southwest to northeast being affected.—*H. C. H.*

HAIL SHOOTING IN ITALY.

The references to this subject in previous volumes of the MONTHLY WEATHER REVIEW have abundantly shown the probability that there is no rational basis for the efforts made in Italy and France to break up thunderstorms and prevent injurious hail by some method of cannonading. Neither the noise, nor the smoke, nor the heat, nor the commotion produced by grand vortex rings can be expected to have any considerable influence on the enormous cumuli from which hail and lightning proceed. This conviction is now confirmed by a report read before the Royal Academy of Sciences at Rome (Accademia dei Lincei), on December 2, 1906, by Senator P. Blaserna, who is also Professor of Physics in the Royal University at Rome, and President of the Accademia dei Lincei. In 1902, Professor Blaserna was appointed by the Italian Government president of a special commission to investigate this subject. A locality that had suffered extremely in previous years was chosen as the field of operations, viz, Castelfranco, in Venetia, and 222 cannon of the most approved special type manufactured by the Greinitz Company were established; each of these sends up a vortex ring 4 meters in diameter, and one additional cannon sending up a vortex 14 meters in diameter was subsequently added. As these vortices failed to ascend higher than 200 or 300 yards they evidently had no effect on the clouds; therefore a higher station, the Casa Aulagne di Monteux, was occupied, so that the vortex rings attained 1200 yards, but still no good results were perceived.

Then the secretary of war and the manufacturers of pyrotechnics were appealed to. Of the latter, Marazzi, at Rome, succeeded in constructing bombs weighing 8 kilograms that were carried up to 800 meters where they exploded. During 1906, 250 broadsides were fired by the 222 cannon at Aulagne, and 60 of the Marazzi bombs were sent up, but still no good effects were perceptible. These negative results of a five-year campaign justify the commission in recommending that the Italian Government no longer encourage such expensive and useless work.—*C. A.*

INFLUENCE OF THE GLASS COVER ON ACTINOMETRIC THERMOMETERS.

By LADISLAUS GORCZYNSKI.

[Translated from Meteorologische Zeitschrift, May, 1907, p. 212-218, by R. A. Edwards.

By actinometric thermometers we mean, in this memoir, mercurial thermometers in which the glass reservoir is not directly exposed to the sun's rays, but is covered by an absorbing layer of lampblack. It is clear that in such a case the primary source of heat variation lies in the absorbing layer of lampblack, so that the thermal condition of the whole thermometric body can not be deduced directly or simply from the indications of its purely thermometric part, i. e., the mass of mercury. It is entirely conceivable that, in some cases, the assumption that the actual temperature variation is identical with that of the mercury may be proper; but with the increasing complexity of the actinometric body the conditions are surely not always so simple, and in such cases a previous investigation of the actual distribution of temperature in the body will be absolutely necessary. It is, therefore, very important that it be clearly understood what is meant by "bodily temperature" in the case of a complex structure.

We will take up only one special case, and consider the actinometric thermometer constructed by Prof. O. Chwolson in 1893 according to the Ångström principle. We will, by this example, show what an important part must be attributed to the glass covering of the actinometric thermometer.

I. We will consider three superposed layers, consisting of lampblack, glass, and mercury.

In Table 1, where these layers are mentioned in their proper order, is given the notation adopted by us.

TABLE 1.—*Location of layers and adopted notation.*

	Thickness.	Temperature.	Surface.	Coefficient of internal conduction.
Air		τ		
Lampblack	d'	θ' outer surface	s_1	k'
Glass	d	t_e outer surface t_i inner surface	s_2	k
Mercury	d''	θ''	s_3	k''

We wish to learn the difference, $\theta' - \theta''$, in case the outer layer of lampblack is exposed to the direct rays of the sun.

If by q we represent the intensity of the energy of the radiation (per unit of time and surface, always assuming a normal exposure), by h the coefficient of external conduction of heat, and by τ the temperature of the surrounding layer of air, we have for the energy that is conveyed to the outer layer of lampblack, the expression

$$q-h(\theta'-\tau) \qquad (1)$$

where the subtrahend expresses the energy radiated from the outer layer of lampblack. This part is assumed to be proportional to the temperature excess, $\theta'-\tau$.

The energy that passes thru any given unit of surface s_1, in the interior of the layer of lampblack, is

$$\frac{k'}{d'}(\theta'-t_e) \qquad (2)$$

Likewise, for a unit surface s_2 in the interior of the glass, the energy will be

$$\frac{k}{d}(t_e-t_i) \qquad (3)$$

where it is assumed that the temperatures in the glass between t_e (at the outer surface of the glass) and t_i (at the inner surface of the glass) have a uniform gradient.

Finally, for a unit surface s_3 in the mercury[1] we have

$$\frac{k''}{d''}(t_i-\theta'') \qquad (4)$$

For a steady state, and under the conditions that obtain for the special case that interests us, we may assume that

$$q-h(\theta'-\tau)=\frac{k'}{d'}(\theta'-t_e)=\frac{k}{d}(t_e-t_i)=\frac{k''}{d''}(t_i-\theta'') \qquad (5)$$

from which we derive

$$q-h(\theta'-\tau)=\frac{\theta'-\theta''}{\frac{d'}{k'}+\frac{d}{k}+\frac{d''}{k''}} \qquad (6)$$

or

$$\theta'-\theta''=\frac{\frac{d'}{k'}+\frac{d}{k}+\frac{d''}{k''}}{1+h\left(\frac{d'}{k'}+\frac{d}{k}+\frac{d''}{k''}\right)}\cdot[q-h(\theta''-\tau)] \qquad (7)$$

The difference

$$\theta''-\tau=T \qquad (8)$$

represents the excess of the temperature of the mercury over that of the air. This excess, which can be easily derived from the observations, we will represent by T. The formula

$$\psi=\theta'-\theta''=\frac{\frac{d'}{k'}+\frac{d}{k}+\frac{d''}{k''}}{1+h\left(\frac{d'}{k'}+\frac{d}{k}+\frac{d''}{k''}\right)}[q-hT] \qquad (9)$$

gives us the desired difference between the temperatures of the mercury and the outer black surface in the case of heating by insolation; the analogous difference (φ) for cooling in the shade will be found directly from the formula (9), by making $q=0$. It is, therefore,

$$\varphi=\theta''-\theta'=\frac{\frac{d'}{k'}+\frac{d}{k}+\frac{d''}{k''}}{1+h\left(\frac{d'}{k'}+\frac{d}{k}+\frac{d''}{k''}\right)}hT \qquad (10)$$

II.—Let us especially consider the formula proposed for the actinometer[2] constructed by Professor Chwolson in 1893, which served to determine the intensity of solar radiation from the simultaneous observations of two "actinometric" thermometers, alternately exposed to the sun and in the shade, respectively.

We do not go into the details of the derivation of this formula, which have been given fully in Chwolson's memoir,[3] and we remark only that his definitive formula has the form

$$q=Kw;\quad K=\frac{2c}{\sigma};\quad w=\frac{1}{t}\frac{\theta_2^2-\theta_1\theta_3}{\theta_1-\theta_3} \qquad (11)$$

where K represents an instrumental constant, c=thermal capacity, σ=absorbing surface, whereas w is given directly by each measurement as a function of t (the interval of time) and θ_1, θ_2, θ_3, which are the simultaneously observed differences of temperature of the two bodies.[4]

The definitive formula has been derived as a particular solution, under certain limiting conditions, which are practically admissible, of the following system of differential equations that expresses the variable thermal condition

$$\left.\begin{aligned} q\sigma dt&=cdT+\sigma hTdt\\ 0&=cdT+\sigma hTdt\end{aligned}\right\} \qquad (12)$$

The first of the two equations that constitute the system (12), and that must hold good simultaneously, relates to the "actinometric" thermometer which is warming under insolation, while the second equation relates to the other thermometer which is simultaneously cooling in the shade. In the deduction of these equations the temperature excesses, T, refer directly to the readings given by the mercurial columns, and it is taken for granted that when the columns of mercury both have the same height in the two thermometers, there is also the same equality of temperature for the glass covers and in general for both actinometric bodies. On the other hand, we will show that in practise it is not to be assumed that the changes of temperature that measure the radiation are the same as those given by the readings of the thermometer. In this connection a change must be made in the definitive formula (11).

III.—We start with the assumption that for values of T simultaneously observed not the system (12), but the differential equations (13) hold good,

$$\left.\begin{aligned} q\sigma dt&=cdT+\sigma h(T+\psi)\,dt\\ 0&=cdT+\sigma h(T-\varphi)\,dt\end{aligned}\right\} \qquad (13)$$

where ψ and φ represent the above-mentioned differences. Since for the Ångström–Chwolson actinometer, the simplifying assumptions—

(a) that the thickness of the layer of lampblack is infinitesimal,

(b) that the thickness of the mercury layer is also negligible, seem to be practically admissible therefore formulas (9) and (10) give the following values for ψ and φ:

$$\left.\begin{aligned} \psi&=\frac{\frac{d}{k}}{1+h\frac{d}{k}}\cdot(q-hT)\\ \varphi&=\frac{h\frac{d}{k}}{1+h\frac{d}{k}}\cdot T\end{aligned}\right\} \qquad (14)$$

If we introduce these values in (13), we obtain a new system of differential equations

$$\left.\begin{aligned} q\sigma dt&=c\left(1+h\frac{d}{k}\right)dT+\sigma hTdt\\ 0&=c\left(1+h\frac{d}{k}\right)dT+\sigma hTdt\end{aligned}\right\} \qquad (15)$$

which exist simultaneously but for two thermometers under different thermal conditions

The differential equations (15) are entirely analogous to

[1] The influence of convection currents on the temperature distribution within the mercury will be neglected.

[2] See Monthly Weather Review, April 1907, pp. 171, 172, and fig. 1.

[3] Aktinometrische Untersuchungen zur Konstruktion eines Pyrheliometers und eines Aktinometers vom O. Chwolson (Wilds Repertorium für Meteorologie 1893). [See also Weather Bureau Bulletin No. 11, pages 721-725.—EDITOR.]

[4] $\theta_1=\theta'-\theta''=\psi$, etc.—EDITOR.

those of (12), from which the definitive formula (11) was derived. We merely have

$$c\left(1+h\frac{d}{k}\right) \text{ instead of } c.$$

We can therefore present the modified definitive formula in the form:

$$q=K'w;\ K'=\frac{2c}{\sigma}\left(1+h\frac{d}{k}\right);\ w=\frac{1}{t}\cdot\frac{\theta_2^2-\theta_1\theta_3}{\theta_1-\theta_3}\ \ldots(16)$$

where w has the same value as previously, but where the factor K' represents not an instrumental constant but a coefficient of transmission that depends on the properties (d and k) of the glass covering, and besides that on the coefficient of external thermal conductivity, h. Since this last varies with the temperature[5] (and indeed increases), so will also the coefficient of transmission simultaneously increase or decrease in the course of the year or the day. Hence, in a series of frequent measurements the variations in the values of K' will be found to proceed in a definite direction, and in the first approximation may also be assumed proportional to the variations of the intensity of the insolation.

The comparative measurements of radiation can give us most reliably some conclusions as to how great these variations are. In fact, the numerous simultaneous observations taken at the central meteorological station at Warsaw during the period 1901–1905 with the Ångström-Chwolson actinometer and the electrical compensation pyrheliometer show that the results deduced from the theory correspond completely with experience. We have found, on an average, for the four actinometers[6], which were compared for this purpose, the following increases in the coefficients of transmission (which themselves all differ but little from unity); i. e., 0.024, 0.005, 0.02, 0.030, respectively, for an increase of 0.1 gram-calories in the intensity of insolation. This difference in the variations of K' is caused by the fact that the properties (d and k) of the glass covering are not the same for all actinometric thermometers, so that the factor $\left(1+h\frac{d}{k}\right)$, even with the same h, can have different values in different thermometers.

We will not, at this time, go further into these experimental comparisons and numerical results, as they may be easily found in our work[7] recently published. We merely remark that the assumption generally made hitherto of a constant value for K' leads to errors in the values of the radiation thus computed that may increase these values by 10 or more per cent of the quantity in question.

The important result of this present article may be summarized as follows: The effect of the influence of the glass covering in actinometric thermometers demands special attention, and the assumption of the identity of the actual temperature fluctuation with that of the mercurial column alone is not admissible without further investigation.

Especially in the case of the actinometer constructed by Professor Chwolson in 1893, the modified formulas show that the earlier so-called "instrumental constant" can be considered only as a variable coefficient of transmission. The values of the intensity of insolation published up to the present time on the supposition of a so-called "constant" are subject to error, and can not be accepted as absolute values in gram-calories until the older values are computed by means of a variable coefficient of transmission.

Supplementary note.—At the latest International Meteorological Conference, which met at Innsbruck in September, 1905, this proposition among others was adopted, viz, that the measurement of the total radiation from the sun should be carried on regularly as far as possible at meteorological observatories and exclusively with the electrical compensation pyrheliometer. Altho this choice, coming from so authoritative a source, is well founded and should receive careful consideration, yet one should not forget that in actual practise one ought not to neglect the thermometric features of the construction of the actinometer. Especially should the present exclusion of the last-named instrument not be considered as a precedent with regard to the future extension of the use of the simple actinometer.

The object in recommending the electrical compensation method exclusively has been to obtain strictly comparable results from various places. It can not be denied that great mistakes have been made in this respect, and that the measurements heretofore made with various actinometers are not comparable among themselves, and almost all fail to give absolute measures. This result is explained by the fact that the older actinometers had not been sufficiently investigated theoretically and experimentally with reference to the accuracy of their data.

In order to improve this condition of affairs Prof. O. Chwolson, as is well known, undertook in 1892 an extensive investigation of all known types of actinometric construction, and in an extensive work demonstrated the fact that none of these actinometers could stand a severe test.

As he favored the first Ångström method he constructed in 1893 a new actinometer, which was known as the Ångström-Chwolson actinometer, and was used in many continuous measurements. This simple and convenient actinometer was constructed on the basis of exhaustive theoretical studies that from a meteorological standpoint can be considered as altogether ideal.

In the treatise above quoted we have shown that even in this actinometer after long practical use still another modification is necessary. It must, however, be carefully borne in mind that this modification applies only to the method of computing the coefficient of transmission (for the conversion of relative measurements into absolute units), and that otherwise the so-called relative values taken directly from the measurements have suffered no variation.

At the same time, we think that in the extensive treatise recently published, as referred to above, founded on numerous comparisons with the compensation pyrheliometer, we have proved that with the Ångström-Chwolson actinometer one can by continuous measurements probably attain an accuracy as great as 1 per cent. This is a limit of accuracy that at present is altogether satisfactory, and can not be much excelled even with regular pyrheliometric measurements.

There is another circumstance of importance, i. e., that in the case of the Chwolson instrument no variation of the coefficient of transmission has been observed with time; this fact makes it possible to send to distant observers actinometers that have been tested at the central station.

We think, therefore, that it would have been entirely in the best interests of meteorological investigation had the following signification been given to the word "exclusive" as used at the Innsbruck meeting:

"For the regular so-called absolute measures of the total radiation of the sun, the electrical compensation pyrhelio-

[5] In every actinometric measurement the value of h is considered as constant and the definitive formulas hold good only in such cases.

[6] It is well at this time to state that in the comparisons of the actinometer with the compensation pyrheliometer the difference of the solid angle under which the radiation is received in the two instruments can be considered as a source of certain variations of the coefficient of transmission (and in the same direction as the influence of the glass covering). Also the use of the simplified formulas in computing the intensity of radiation can eventually give rise to certain variations. (See article referred to below.)

[7] Ladislaus Gorczynski. Sur la marche annuelle de l'intensité du rayonnement solaire à Varsovie et sur la théorie des appareils employés, p. 202. (Avec 2 planches.) 8vo. 1906.

meter only can be recommended for the present; all relative measures (i. e., measures taken with the actinometer) should be compared with this pyrheliometer exclusively. As an actinometer for regular use we can for the present recommend the Chwolson instrument".

The requirement that the relative actinometric measures be reduced to the above-named pyrheliometer exclusively implies, of course, that these actinometric values, as a whole, are capable of being thus reduced. The words "for the present" are added, because among pyrheliometers the Ångström compensation method and among actinometers the Chwolson construction naturally can have the exclusive preference only as long as no new instruments, more reliable, simple, and practical, are invented.

REPORT ON THE GREAT INDIAN EARTHQUAKE OF 1905.

By C. F. MARVIN, Professor of Meteorology. Dated September 14, 1907.

The above is the title of the latest issue of the Publications of the Earthquake Investigation Committee of Japan in Foreign Languages, Nos. 23 and 24, and comprises the elaborate and detailed report by Dr. F. Omori on the great earthquake which, at an early hour in the morning of April 4, 1905, Greenwich mean time, devastated a large section of northern India. The following is a summary of some of the many valuable points presented in Doctor Omori's report:

Origin.—The epifocal zone formed an elongated tract extending northwest and southeast for a distance of about 170 miles, approximately parallel to the trend of the subHimalayan chains of the Punjab. The geographic coordinates of strongest surface motion are considered to have been about longitude 77° E. and latitude 31° 49′ N. No great surface faulting or dislocation of the ground seems to have occurred or been manifest, and it would therefore appear that the origin of the disturbances must have been deep below the surface.[1] This conclusion is also suggested by a consideration of the wide extent of the region of sensible motion.

Intensity.—The earthquake was felt at an extreme distance of over 1000 miles, and serious damage was effected over a region of about 2150 square miles, an area slightly greater than that of the State of Delaware.

Omori states that "the total number of the houses destroyed in the Kangra district and the Mandi state amounted to 112,477, and the number of persons killed reached 18,815, exceeding any similar record of great seismic catastrophes in recent times"[2].

In connection with the great fatality of the Indian earthquake it is pointed out that the customary type of building within the stricken districts is constructed with walls of mud or rubble masonry, surmounted by heavy slate roofs, and is wholly unsuited to resist seismic action. In fact a massive, thick-walled house of inferior masonry work is shattered down at once by an earthquake shock into a heap of stone, with great loss of life to the inmates; whereas properly built wooden or steel-frame structures can resist almost any shock whatever.

The real measure of the intensity of earthquake action is the maximum acceleration of the vibratory motions of the ground at any place. In the absence of accurate automatic records this can sometimes be deduced approximately from various observed effects, and Omori gives the following values:

Upper Dharmsala: Maximum acceleration not greater than 2300 millimeters per second per second.

Kangra: Maximum acceleration not greater than 3500 millimeters per second per second.

Palampur: Maximum acceleration not greater than 2350 millimeters per second per second.

Mandi: Maximum acceleration not greater than 2280 millimeters per second per second.

In the great Japanese earthquake of 1891 the maximum acceleration in the Mino-Owari plain exceeded 4000 millimeters per second per second, and was much higher in the epicentral zone of the famous Neo Valley. Omori elsewhere states that the maximum acceleration in the San Francisco disturbance probably did not exceed 2600 millimeters per second per second. He also states that the minimum acceleration perceptible to the average individual is about 17 millimeters per second per second. It may be added that the acceleration of gravity at the surface of the earth, exprest in the same units employed above, is about 9800 millimeters per second per second.

Time of origin.—Seismographic records of the Kangra earthquake were not obtained anywhere within the zone of sensible motion. At Dehra Dun, however, about 120 miles southeast of the center of strongest motion, a valuable record for time determination was obtained on a magnetograph. This and similar records at Barrackpore, Kodaikanal, and Taungoo were carefully analyzed by Captain Thomas, in charge of the the magnetic department at Dehra Dun, and after eliminating, as far as possible, clock errors, etc., and allowing for the respective distances from the epicenter, the time of the beginning[3] of the earthquake at the epicenter was adopted by Omori as being $0^h, 49^m, 48^s$, Greenwich mean time, April 4, civil reckoning.

Automatic records.—The major part of the report now under consideration is devoted to a detailed analysis and discussion of a large number of automatic records of the earthquake obtained at seismological observatories all over the world.

About 70 seismograms from 51 stations were available. A most valuable feature of the work is the reproduction, in original size, of 41 different seismograms from instruments of greatly varied type. These plates, with short explanatory text, constitute the material of No. 23 of The Publications. Not only are we able from these records to have before us a graphic picture of the earthquake motion at different places all over the world, but we are at the same time able to compare actual records from many different types of seismographs.

Results.—It is now generally known that unfelt earthquake motion as revealed in teleseismic records consists of several more or less sharply defined phases, or sections, and the analysis of the seismograms from this point of view has been carried out by Omori in considerable detail.

The record of an earthquake as it appears upon a seismogram is considered to have been produced at any given station by the arrival of earthquake motions propagated over the short, or minor, arc of the great circle passing thru the station and the origin. This primary motion Omori describes broadly as the W_1 motion, as distinguished from the motion which is propagated from the origin over the major arc of this same great circle, and which therefore must arrive later at the given station from the opposite direction This latter motion Omori calls the W_2 motion. Finally, he recognized a W_3 motion; this is the W_1 which, after passing the station, ultimately returns after completely circumnavigating the globe.

The W_2 and W_3 motions are generally superposed upon the so-called "end portion" or "tail" of the earthquake record, and are seldom sharply defined or clearly differentiated from the other features of the disturbance. Obviously, if a station is at a great distance from the origin, that is, near the antipodes, the motions propagated along the major and minor arcs must be very largely confused and superposed.

The primary motion (W_1) is subdivided by Omori into "first

[1] Probably not over 20 or 30 miles.—*C. F. M.*

[2] Excepting the north Japan earthquake of June 15, 1896, which caused great tidal disturbances along the northeastern coast of Japan, resulting in the death of 21,953 persons.

[3] In the Monthly Weather Review for April, 1907, p. 160, I have given reasons why the time of beginning of strong motion at the origin of an earthquake, and not the beginning of small tremors, should be regarded as the starting point for the discussion of long distance transmission of waves. In the present case we should conclude from the data employed that the strong motion at the epicenter began at about $0^h, 50^m, 08^s$, Greenwich mean time.